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REPORT ON SURVEY OF THE CANNING TOMATO INDUSTRY
WITH SUGGESTIONS FOR IMPROVEMENT

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THE PROBLEM

Early in 1922 a conference in San Francisco upon the tomato-growing industry was arranged by the Cannerymen's League of California, in order to consider means and methods of bringing about improved conditions. At this conference various private, corporate, state and federal agencies interested in this subject were represented. The principal conclusions reached emphasized the needs of the industry along the line of disease control and variety improvement. As a result of this activity, Mr. Michael Shapovalov of the United States Department of Agriculture was assigned to work in California upon the investigation of tomato diseases, particularly that called western blight and the seemingly related wilt. Mr. Shapovalov located at the Citrus Experiment Station of the University of California at Riverside, and is still continuing in the work of disease investigation. On the part of the Agricultural Experiment Station, Mr. J. W. Lesley (Genetics) undertook the work of breeding disease-resistant and otherwise desirable tomato varieties, while the writer was detailed to make a survey of the conditions and methods actually existing in the tomato-growing industry and to suggest practical possibilities of immediate improvement.

This work has had to do almost entirely with the growing of canning tomatoes in the San Francisco Bay region. The situation has been stated as follows: "The canners have become alarmed at the decreasing yields per acre and the inclination of growers not to grow tomatoes because of the low yields and the low price which the canners are forced to offer on account of the class of fruit produced." In the absence of specific information and without any very definite evidence, the disease called western blight has been looked upon as the cause of much of the trouble.

PLAN OF THE WORK

The work has consisted in systematic observation of most of the tomato fields in the Bay region, together with frequent trips to the lower Sacramento and San Joaquin valleys and occasional visits to the upper San Joaquin and southern California during the seasons of 1922 and 1923. In 1922, an experimental variety planting was made at Manteca, San Joaquin County. In 1923, more extensive variety tests were made at San Jose, Hayward, Manteca, and Folsom. Canning tests and other miscellaneous work was done at San Jose.

The aim has been to learn existing conditions in the tomato-growing industry by means of field observations and studies as to the prevalence of diseases, methods of growing and handling the crop, and the value of different varieties. The general idea has been to learn what can be done for the improvement of the industry by the application of existing knowledge rather than to inaugurate research into entirely new fields. Much of the work has been done in close coöperation with Messrs. M. Shapovalov and J. W. Lesley, although their work was more particularly on other phases of the problem and centered largely in southern California. The identification of diseases has been very largely corroborated by Mr. Shapovalov or by members of the Division of Plant Pathology at Berkeley. The identification and estimation of varieties and the discussion of cultural methods are based on the writer's personal judgment.

In presenting this report, the method followed will be to give a brief description of the methods, varieties, etc., now in use, and the conditions and information now existing, followed in each section by a paragraph embodying the writer's conclusions and suggestions as to possibilities of improvement in this particular respect. The description of prevailing methods and conditions is given simply to present these suggestions intelligently and not with the idea of writing a circular of information on tomato growing. Such a publication has recently been issued by this Station.¹

NATURE OF THE INDUSTRY

The tomato industry in California separates quite naturally into two divisions: production for the canneries, and production for the fresh fruit shipment. In some sections there is an overlapping of these two lines of production, but generally they are fairly separate.

¹ Rosa, J. T. Tomato production in California. Calif. Agri. Exp. Sta. Circ. 263, pp. 1-19, figs. 1-6. 1923.

The principal canning districts are in the vicinity of San Francisco Bay, especially about San Jose and Hayward and extending northeast and south to a considerable distance, and in the vicinity of Los Angeles. Imperial Valley produces tomatoes extensively for early shipment and the crop is grown locally in many other parts of the state.

The growing of tomatoes in California does not constitute a **major** business with many land owners. There are no tomato growers in the sense that there are pear, prune, apricot, and even potato growers. The tomato is grown largely by renters on a share basis and usually as a temporary crop. It is used also to a large extent as an intercrop in young orchards or on land which is destined eventually to be planted in orchard. Consequently, very few land owners have any permanent interest in the success of the tomato industry. This being the situation, any concentrated or sustained effort toward improvement must come from canners or shippers, or from some other agency which has a permanent interest in the product, rather than from the growers themselves.

PROPAGATION

In the commercial propagation of tomatoes, several methods are employed, depending largely upon the location and the season of the year. During the winter months both hotbeds and cold frames are used for seed planting, and cold frames for transplanting from hotbeds. During the milder seasons of the year, seed are sown in open beds, and in the Manteca district the seed are planted at proper distances directly in the field. This is the only northern section in which field planting of seed is done and the practice is supposed to have originated as a means of controlling western blight. During 1922 and 1923, western blight has not been prevalent in the Manteca district, therefore no observation has been possible as to the effect of field-planted seed in the control of this disease.

In southern California the tomato season extends from April to December and seed planting dates vary with locality rather than with season. Plants are produced in this section in hotbeds, cold frames, and open beds. In the Imperial Valley some acreage is field-planted; here also the young plants are protected by the use of paper caps and small brush and weed structures about each plant. In the Bay region, tomato seed is planted in cold frames, beginning January 1st and ending about March 1st. Transplanting in the cold frames is practiced for the earliest plants, while the later plants are transplanted to open beds as well as into cold frames. Those growers who do not transplant

into cold frames, sow the seed rather thinly to provide room for the seedlings. Transplanting, however, is quite generally practiced. In the central valley section, seed-planting in hotbeds begins January 1st and the plants are not usually transplanted either within the hotbeds or to cold frames. The seed are broadcast rather thinly and the plants

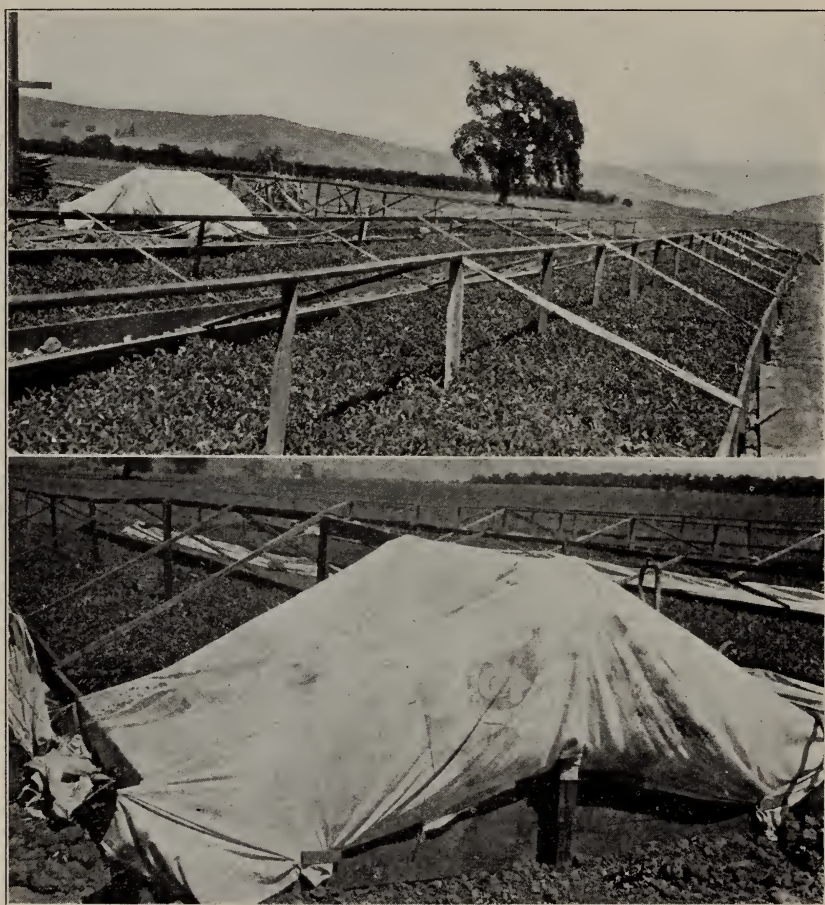


Fig. 1.—Cold frame seed bed as used in the San Francisco Bay region for starting tomato plants. These beds are usually planted in January, giving large, three- to four-months-old plants for field planting in May. Seed planting in late February or March, producing smaller, younger plants for field planting with less breakage of roots and less shock in transplanting, is recommended to prevent disease.

after hardening are transplanted directly to the fields. In the Bay region most of the plants from seed planted January 1st are set in the field about May 1st, although some field-planting begins about April 15th. Under this practice the plants are from three to four

months old when set in the field. In the Merced district, plants from seed planted January 1st are planted in the field during March and commence producing fruit by June 1st.

Recommendations.—Tomato plants about eight inches high are best for field planting. This size should be reached in from six to eight weeks. Under the practice in the Bay region of planting seed in January for field planting in May, the plants are from three to four months old when set in the field. While such plants are large-sized, it is doubtful if the results are as good as those obtained with plants from seed sown about March first. Plants held too long in the seed bed or cold frame undergo a check before being moved to the field and the shock of transplanting is more severe in large than in small plants. There is also more breaking of roots and underground injury, which may have a rather direct relation to diseases which will be discussed under that heading. Later planting of seed beds (February 15–March 1), resulting in the field-planting of younger, smaller plants (6–8 weeks old, 8 inches high) is strongly recommended for the Bay region. This method has proved satisfactory after definite trial on a considerable scale and it is believed that its general adoption would result in less disease and increased production per acre.

FIELD PRACTICE

The practice in many states of growing tomatoes in high ridges or on two-rowed beds for the control of fruit rots caused by soil fungi is not followed in California. In this state the field, after it has been prepared by plowing and harrowing, is usually furrowed with a plow at the planting distance desired and the plants are set on the side of the furrow, following immediately with an irrigation. With each successive cultivation the land is turned toward the plants until the irrigation furrow is in the center of the row and the general effect is as though the plants had been set in the center of a wide, low bed.

Planting distances vary from 7 by 7 feet to 16 inches apart. The usual distances are 6 by 6 feet and 6 by 4 feet. The most radical departure in tomato growing is to be found at Merced. Here the tomatoes are set about 16 inches apart in rows only 3 feet apart and the plants are pruned to two stems and trained up on stakes. This method prevails only in the production of tomatoes for market, and of course makes necessary a great amount of hand labor. The average field of stake-grown tomatoes is small, not being much larger than can be cared for by the grower himself and his family. It is the most intensive system practiced in California tomato-growing.

FERTILIZATION

It is the experience of tomato growers (as with growers of many other crops) that it is only on new land that maximum production is obtained. If continuous planting on the same land is practiced, the yield ordinarily declines rapidly. Reasonably accurate figures in a typical case of a field of about forty acres show a production for 1920 of 900 tons, for 1921 of 600 tons, and for 1922 of 400 tons. What part of this rapid decrease in tonnage may be charged to soil changes, crop residues, faulty growing conditions, increase of parasites, or other factors is not known.

Commercial fertilizers have been used only to a very limited extent in tomato growing in California. The results have not been encouraging, whether because of an improper selection of materials or because of insufficient amounts applied has not been determined.

ACREAGE

During 1922, it was estimated that the acreage under contract for the canneries was between 17,000 and 18,000 acres. During 1923, the estimated acreage under contract for the canneries was over 22,000 acres, with an equal acreage employed in the growing of tomatoes for shipping and market, making a total of approximately 45,000 acres devoted to the production of tomatoes in 1923.

Recommendations.—The writer has no very specific suggestions as to improvement of field practice with tomatoes in the Bay region. Methods which apply generally to the culture of all field crops, such as thorough preparation of the soil, maintenance of an adequate moisture condition and thorough cultivation after irrigation as late in the season as this can be practiced, cannot be over-emphasized. Beyond this, the greatest possibilities of increasing crops and improving quality through cultural means may be in soil fertilization, but this is yet to be proven.

HARVESTING

Tomatoes for the canneries are ready in August and the harvest is in full swing by September 15. The season continues usually until late November, or until frost or rain ruins the fruit. Gathering in baskets is the common practice. As the baskets are filled, they are carried to the ends of the rows and emptied by pouring the fruit into lug boxes. Some growers gather in lug boxes, but this is considered bad practice and should be prohibited by the canneries. A lug box is so large that a picker can walk around the box and throw fruit into

it, which he usually does. When the box is half or more filled, it becomes so heavy that the picker handles it roughly, the result being that the ripe fruit is crushed and broken before it leaves the field. The common practice is to haul directly from the field to the cannery. In some instances the boxes are hauled to a loading platform and then loaded onto trucks or wagons for hauling to the canneries.

Only full ripe fruit is acceptable for canning and for other tomato products and when in this condition the fruit is easily injured by rough handling. Many pickers handle the fully ripe fruit as though it had the durability of cobble stones. The loaders and unloaders handle the boxes too often with unnecessary roughness. The losses resulting from bad handling hurt both the grower and the buyer, but the grower must suffer the greater loss.

Recommendations.—The tomato gathering season, for delivery to the canneries, is too long. The season generally ends only on account of its termination by unfavorable weather. The fruit begins to ripen by August 15 and should there come a heavy frost by October 15, the average grower loses approximately half of his possible crop, because it has not matured before this date. The season for gathering can undoubtedly be shortened by the intelligent selection of plants and fruit for seed, thus obtaining a strain or variety which matures the bulk of its crop within a shorter period than at present. In the effort to obtain such a variety, other qualities such as disease resistance, canning quality productivity, etc., must also, of course, be considered.

VARIETIES

The number of varieties of tomatoes grown commercially in California is comparatively small. In the southern part of the state the Stone holds first place for both shipping and for canning purposes. Earliana and strains of Earliana are grown for the earliest shipments, followed by Stone for the main crop. Globe is also being grown. The Stone is practically the only variety being used by the canneries in the south, except that over-ripe Earliana and other varieties are utilized in the making of sauce, paste and puree. In the northern part of the state the variety commonly called "Jap Canner," "Canner," and "San Jose Canner" is the most largely grown variety for the canneries. In the interior valley sections, the Stone is almost the only variety grown for the canneries. For shipping purposes the Earliana and strains of this variety are grown for earliest shipping, followed by Stone for the main shipping crop. In the section about Center-ville and Irvington it has been found that the variety generally grown there and called Stone is in reality not Stone at all, but a somewhat degenerated strain of the Morse San Jose Canner.

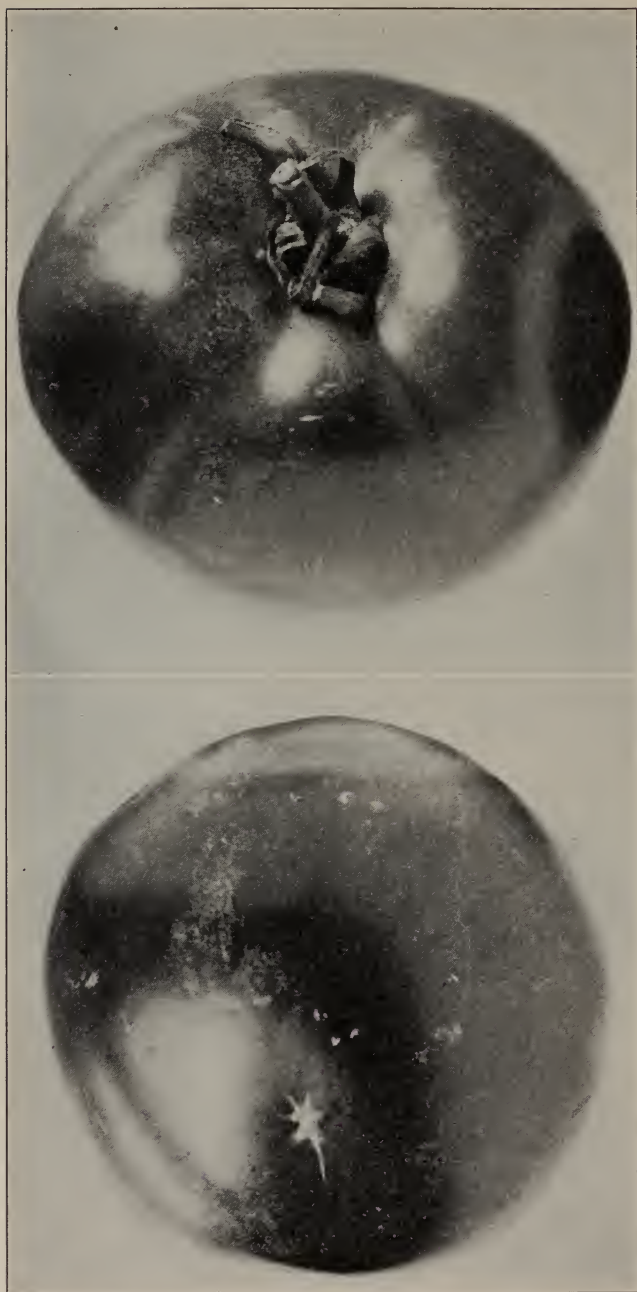


Fig. 2.—Stone tomato, grown largely for shipping and canning. Very susceptible to disease and should be replaced by Norton and other resistant varieties.

Stone.—This is at present the leading variety in the state as a whole, being extensively grown for both canning and shipping in the south and in the interior valleys, and for shipping purposes in the north. It is a variety of luxuriant growth and heavy bearing. The fruit is of bright red color and good size, smooth and symmetrical in form, and of firm, solid texture. It is not an early bearer and therefore not adapted to planting for early shipment. The great defect of Stone is its susceptibility to disease. In other parts of the country it is known to be one of the varieties most susceptible to *Fusarium* wilt, and the same is true in California. In relation to other diseases, the Stone is as susceptible as any other variety and suffers great annual losses from such causes. It has no marked superiority in any way over certain other varieties and there is, therefore, no reason why it should be considered desirable for continued planting.

Recommendation.—It is recommended that the Stone be replaced at present for canning by Norton or Norduke, both of which are of Stone type and red in color. These have shown themselves to be as resistant to wilt in California as elsewhere and appear to have all the good qualities of the Stone. Globe, a resistant pink variety, is recommended to replace Stone as a shipper. Norton (red) is also good for shipping.

Canner.—The variety commonly grown for the canning trade in the Bay region is the “Canner” (“Jap Canner,” “San Jose Canner”). On both sides of San Francisco Bay and as far south as Hollister this is almost the only variety grown for the canneries and undoubtedly furnishes the greatest tonnage of any and all varieties grown for canning in this state. The “Canner” is a strain of the old Trophy which apparently was originated by selection in the San Jose district. It has the bright red color, “meatiness,” and flavor desired by the canners and is a general favorite with those now growing tomatoes for the canneries. In the Bay region it is a very heavy bearer, yields of 30 tons or more per acre being known, while production of 20 to 25 tons per acre is fairly common. The entire acreage under contract to one of the canneries during 1922, averaged an acre production of 11 tons delivered to the cannery. The average production of tomatoes for the state is only 4 to 5 tons per acre. The Canner variety makes an excellent canned fruit, puree, sauce, ketchup or paste. It is a very large tomato, made up of thick outer walls and inner divisions with small and broken cells. It gives a large percentage of solid as compared to liquid content. The strain commonly grown for packing is badly degenerated. This has been brought about by lack of intelligent selection as it is likely that the bulk of the seed planted is from nothing better than culls. The best average of the fruit is not over half smooth

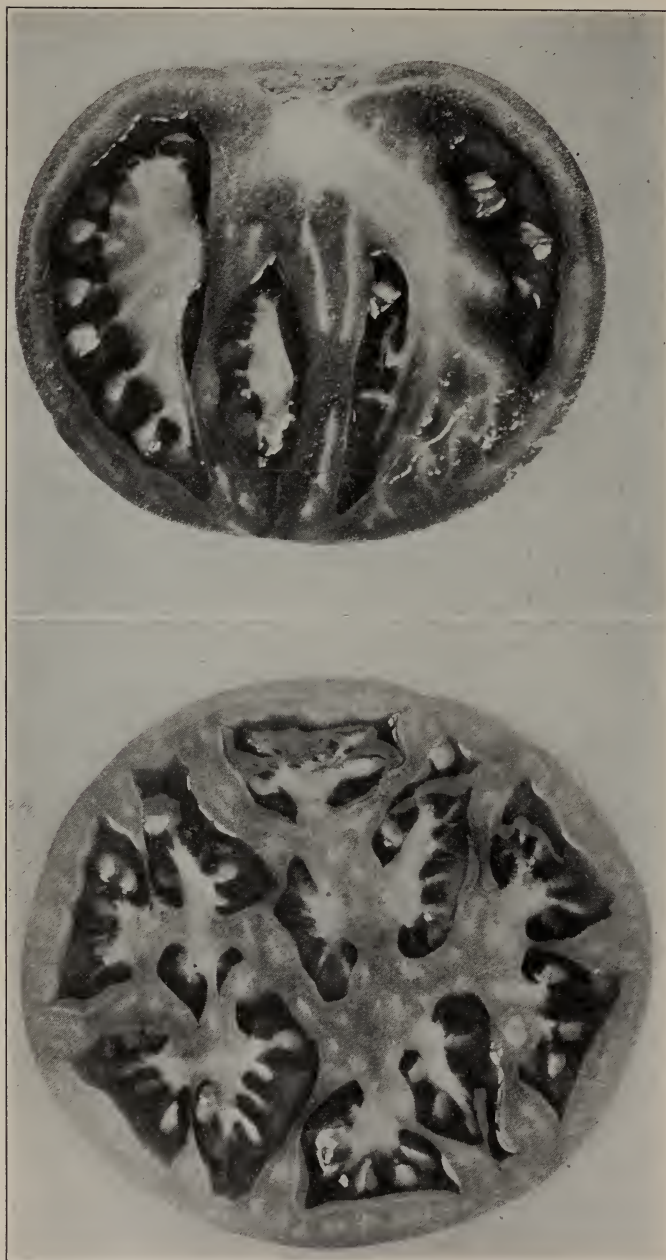


Fig. 3.—Sections of Stone tomato.

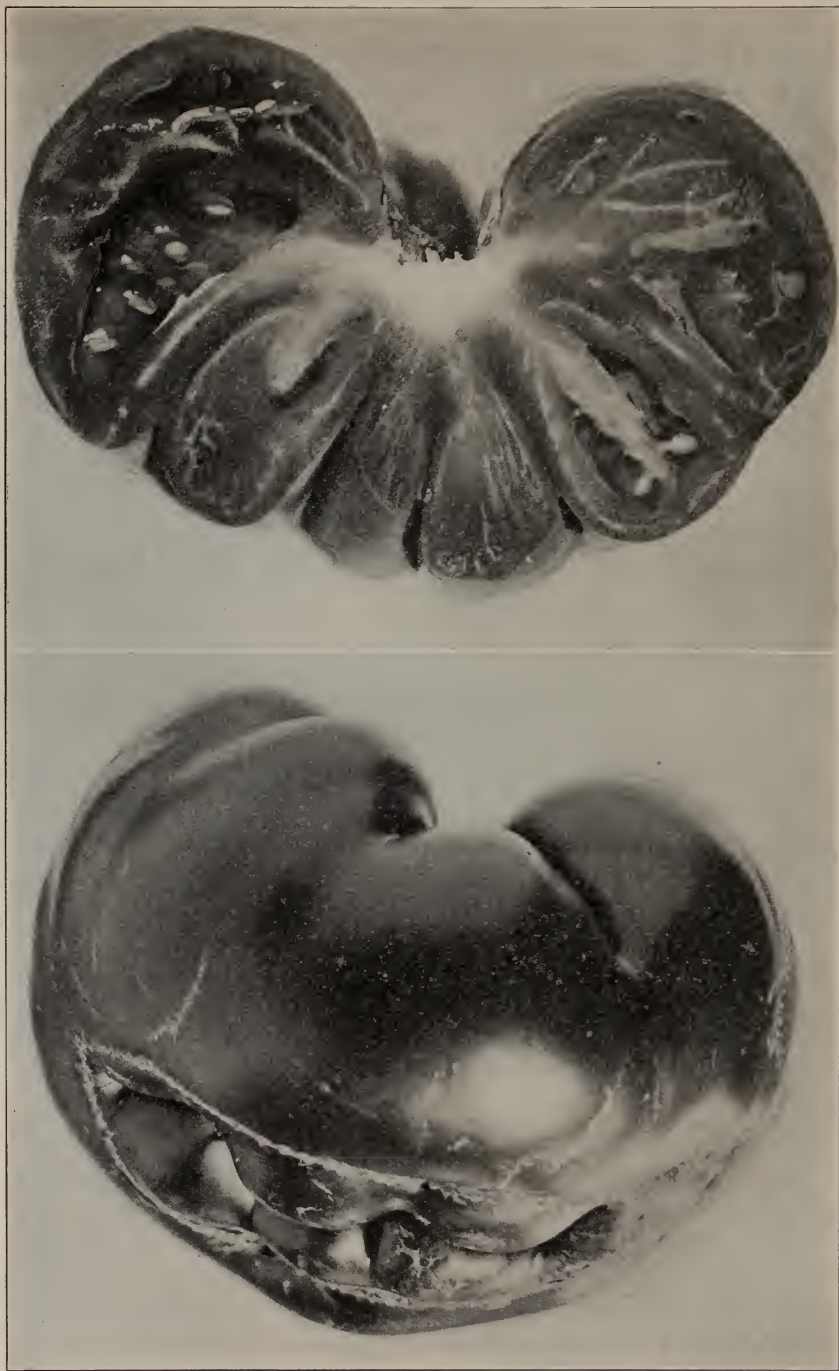


Fig. 4.—“Jap Canner” tomato. This is at present the most popular variety in the Bay region for canning, on account of size, heavy production, color, flavor and high percentage of flesh. The variety is superior in all these respects and has some disease-resistance. It needs improvement by selection in shape, amount of core, time of ripening and disease-resistance.

or fairly smooth tomatoes. The fruit is large, flat, with a deep stem cavity, and rough at both the stem and blossom ends. This roughness is responsible for the introduction of active yeasts and moulds into tomato products and also for a large cannery waste.

The "Canner" has a large white or greenish core extending from the stem end almost to the blossom end of the fruit. The removal of this core undoubtedly involves the greatest waste of any of the cannery operations. So large a piece of the fruit is removed with the core that the locules are opened and subsequent handling causes loss of jelly, seeds, juice, and a considerable amount of tomato flesh. The average size of "Canner" tomatoes delivered to the cannery is too large for canning purposes; the diameter of the fruit should not be larger than that of the container. The season required for maturing "Jap Canner" fruit is altogether too long, resulting in the loss of a large part of the crop in years when early frosts or heavy rains occur. This variety appears to have some resistance to *Fusarium* or wilt disease, more at least than the Stone.

The "Canner" at present is undoubtedly the best commercial canning variety for both grower and packer on account of its heavy production and the color, solidity, flavor, and high percentage of solids of the fruit. Both production and quality are sustained late in the fall. The variety shows considerable disease resistance in the Bay region. On account, however, of the serious defects of oversized, unshapely, rough fruit with an exaggerated core and the long season required for maturing the crop, together with the need of increased disease resistance, there is great room for improvement in this variety.

Recommendations.—Efforts should at once be made to improve the "Jap Canner" variety by selection in the field, in respect to smoothness of fruit, amount of core, length of time required for maturing the bulk of the crop, and in disease resistance. This variety has so many good qualities and is so firmly established in the Bay region that the gradual development and introduction of an improved strain seems more practical than attempting to introduce an entirely new variety.

Morse's San Jose Canner.—This variety or strain has been developed through several years' careful selection from the "Jap Canner" in an effort to obtain a smoother and more uniform fruit. This goal has been attained to a very considerable extent. The Morse Canner has not as yet, however, attained a very firm place in the tomato-growing industry, possibly for some of the following reasons: On all kinds of ground it will not produce as heavily as the "Jap Canner." On new, heavy ground, however, the "Morse" may produce even more heavily than the "Jap," as the latter, under these condi-

tions, is inclined to produce vine at the expense of fruit. On lighter or old tomato ground the extreme vigor of the ordinary "Canner" gives superior yields. Crops of over twenty tons per acre have been recorded with "Morse Canner" in 1923. In quality, there is considerable experience to show that in the first half of the crop the "Morse" compares favorably with the "Jap Canner" for percentage of solids to liquids, but in the latter part of the crop the tomatoes are inclined to be small and soft. This seems to be the worst fault of this variety in the eyes of



Fig. 5.—Morse strain of San Jose Canner. Much improved in shape.

growers and canners. Also the necessarily high price of seed for a carefully selected strain which produces very little seed per ton of tomatoes, as compared with seed from ordinary sources.

Norton.—This variety originated as a selection from the "Stone," made by J. B. Norton of the U. S. Department of Agriculture. It is indistinguishable from a good strain of Stone in yield and character, but has the very great advantage of a high degree of resistance to Fusarium wilt. This quality has been found to hold good in California. Norton is therefore recommended for planting instead of the Stone. "Norduke" is very similar to Norton.



Fig. 6.—Sections of Morse strain of "Canner" tomato.

Globe.—The Globe is a deep, globular-shaped tomato of pink color. It is probably the most resistant to *Fusarium* wilt of any of the older commercial varieties. Large acreages of Globe are planted by seedsmen in southern California with entire success. The variety is being

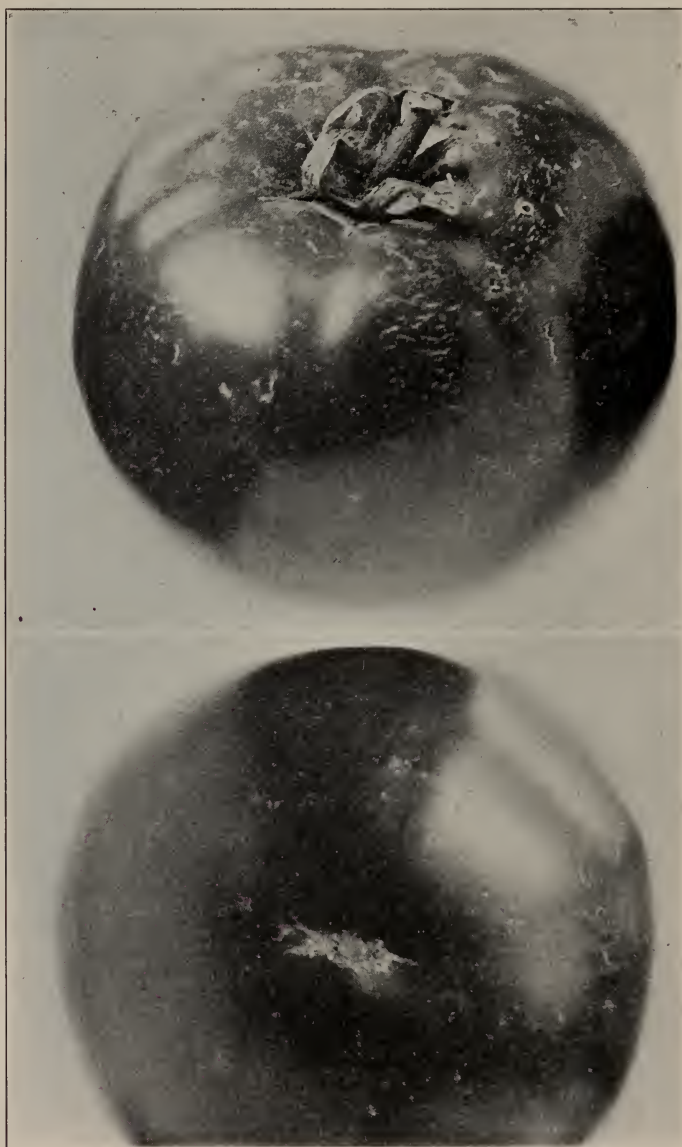


Fig. 7.—Norton tomato. A disease-resistant selection of Stone.

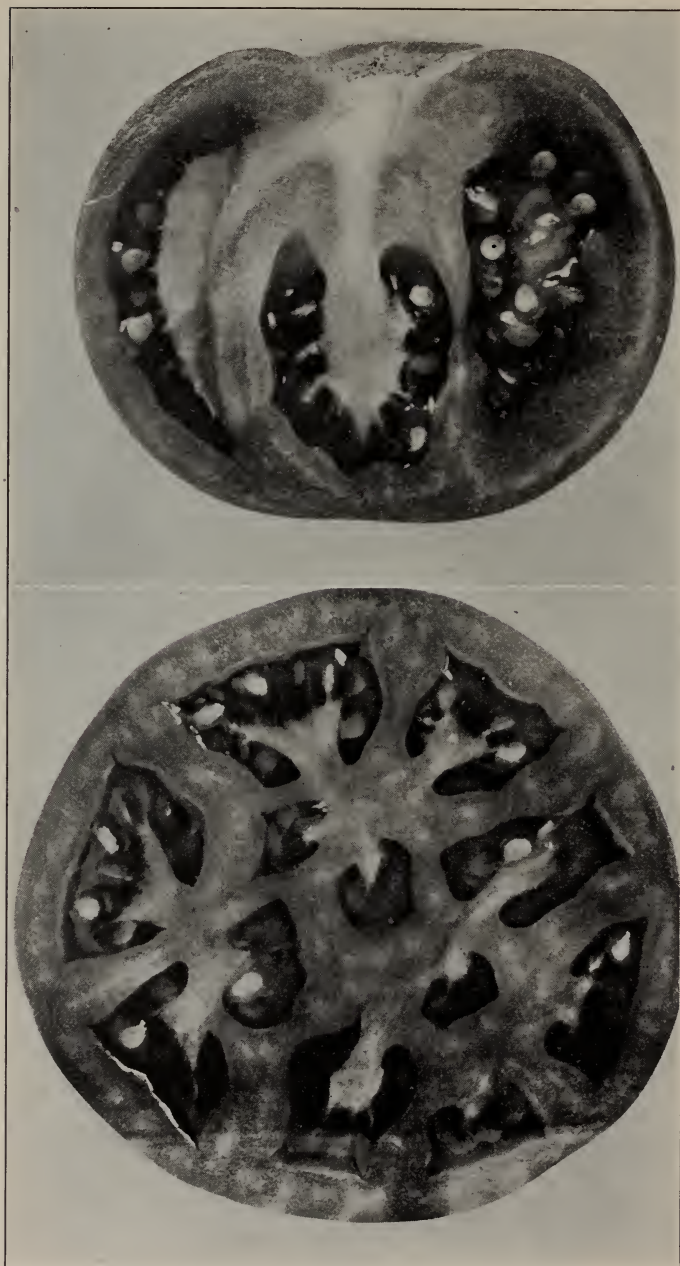


Fig. 8.—Sections of Norton tomato.

grown in California for shipping to a certain extent and from present indications should replace the Stone for this purpose, on account of its resistance to disease.

Diener.—This appears to be a typical strain of “San Jose Canner,” with the heavy production and rough fruit characteristic of this variety.

Other Varieties.—Many other tomato varieties are grown in California and elsewhere, but none have thus far shown qualities which recommend them above those already described. The following have been grown experimentally or closely observed in this work: Arlington, Burbank, Columbia, Earliana, Greater Baltimore, Louisiana Pink, Louisiana Red, Marvel and Trophy.

DISEASES

In this survey attention has not been paid to all the diseases of the tomato, but simply the most important ones which more or less regularly affect the yield of canning tomatoes.

Western Blight.—The losses supposed to be due to this disease were largely responsible for the present work being started. The writer found, however, very early in his survey that “Blight” is a very vague term in the minds of most California tomato-growers. It appears that for many years there has occurred in California a dying of tomato plants in the field which causes various degrees of loss in different seasons, but a serious amount in the aggregate. This trouble has usually been greater in the warmer parts of the state and of less extent near the coast and in the Bay district, although it is reported as having been abundant in some seasons in the latter region. Some even state that the occurrence of this “Blight” is the only factor which prevents the extensive growing of canning tomatoes in the interior valley of California. There seems from the first to have been much doubt concerning the identity and nature of this disease. Nearly twenty years ago R. E. Smith² stated that “This trouble has been commonly referred to as the bacterial blight, an eastern tomato disease. It is not that disease.” Smith considered the disease to be due to a soil fungus, a species of *Fusarium*, which attacks the roots and thereby weakens and finally kills the plant above ground. He states, however, that “If a plant is pulled up as soon as it begins to show wilting and fading, the roots look healthy and sound,” but thinks that the trouble starts at the ends of the roots. The further opinion is expressed that this disease

² Smith, R. E. Tomato diseases in California. Calif. Agr. Exp. Sta. Bull. 175, p. 7. 1906.

is not the well-known tomato wilt of the eastern states, caused by *Fusarium lycopersici* Sacc., but a different disease. Smith calls this disease "Summer Blight." The same writer in a later publication³ suggests that "it is possible that two different diseases are confused in this trouble." Rogers⁴ in 1912 described this disease under the name of "Summer Blight" or "Wilt" and states that it has been the cause of enormous losses in California through the dying of plants in the field. This author states that "The roots of a plant affected by the wilt appear to be normal." A large amount of negative or inconclusive and therefore unpublished work was performed by Rogers upon the nature of this disease. He considered "Summer Blight" to be entirely distinct from the true *Fusarium* wilt and suggested the possibility of its being a mosaic or systemic disease. Humphrey⁵ in 1914, described under the name "Yellow Blight" a tomato disease of the Pacific Northwest. This disease appeared to bear considerable resemblance to that occurring in California. Humphrey considered Yellow Blight to be due to two species of *Fusarium*, *F. orthoceras* and *F. oxysporum*, attacking the roots during periods of high temperature, intense light and low humidity, and believed the disease to be distinct from the usual tomato wilt caused by *F. lycopersici*. Subsequent work by Hall and by Heald, referred to very briefly in several annual reports of the Washington Station, suggested another soil fungus, *Rhizoctonia*, rather than *Fusarium*, as the cause of this trouble in the State of Washington. Previously in Idaho, Huntley,⁶ and Henderson⁷ mentioned a tomato "Blight" or "Yellows" which appears to be similar to the disease under discussion. The name "Western Blight" seems to have originated in the United States Department of Agriculture as a designation of this more or less well-defined tomato disease of California and the Northwest. The name was used by Orton⁸ as early at least as 1907.

The writer's observations in California during the seasons of 1922 and 1923 strongly bear out the conclusion that two different diseases

³ Smith, R. E., and Smith, E. H. California plant diseases. Calif. Agr. Exp. Sta. Bull. 218, p. 1168. 1911.

⁴ Rogers, S. S. The culture of tomatoes in California with special reference to their diseases. Calif. Agr. Exp. Sta. Bull. 239, pp. 612-615. 1923.

⁵ Humphrey, H. B. Studies on the relation of certain species of *Fusarium* to the tomato blight of the Pacific Northwest. Washington Agr. Exp. Sta. Bull. 115, pp. 1-22, plates, 1-4. 1914.

⁶ Huntley, F. A. Tomato culture. Idaho Agr. Exp. Sta. Bull. 34, pp. 108-117, figs. 1-3. 1904.

⁷ Henderson, L. F. Tomato Blight. Ann Rept. Idaho Agr. Exp. Sta. pp. 28-32. 1904.

⁸ Orton, W. A. Tomato Diseases. In Tomato Culture, by W. W. Tracy. Orange Judd Co., New York.



Fig. 9.—The disease called tomato “Blight” in California; typical fields. This has been supposed to be Western Blight, but it appears that much of the trouble is due to *Fusarium Wilt*, a disease which can be controlled by planting resistant varieties.

have been confused under the general term "Blight," one of these resembling the usual *Fusarium* wilt common to many parts of the country, caused by *Fusarium lycopersici* Sacc., while the other may be termed true western blight, the cause of which is still unknown. It is also concluded that in the years mentioned wilt was a much more serious factor than western blight.

Western blight, as the writer distinguishes it in California, is characterized by the rolling, with an upward inclination, of the leaflets, which become stiffened and somewhat thickened. These stiffened leaflets have a suggestion of brittleness when pressed with the fingers. As the disease progresses in the plant, the leaves take on a peculiar sulfury yellow color which is so characteristic as a symptom of western blight that it can scarcely be mistaken for any other disease. The veins of the leaflets nearly always become of a purplish to deep purple color, although this purpling of the veins should not be considered as a necessary symptom of western blight. During 1923 purpling has been much in evidence on the foliage of those plants which developed symptoms of western blight late in the season. In many instances the whole leaf surface has become purpled as well as the veins. In western blight the stems and branches of the plant appear to be normal except that they are dry inside, indicating that the ability of the root system to take moisture from the soil has been seriously impaired. The root system shows symptoms of western blight in its dead and dying roots. The smallest roots die first, the infection working gradually through the roots until it enters that part of the plant stem below ground. When this has occurred, the plant is usually nearly done for. There is a slight discoloration in the roots a short distance ahead of the dead or dying part, this being more pronounced just under the cortex. As the root dies, it becomes much shrunken. When the disease has progressed far enough to be readily distinguishable, the plant has stopped growing and we have never seen a plant which showed infection in the spring that has grown further. Among those plants which did not develop typical symptoms until fall, certain plants have been observed which were apparently in a growing condition and also affected by western blight. It is our conclusion, however, that when a plant shows symptoms of being affected by western blight that it will never grow any more. Plants affected by western blight seldom produce fruits approaching normal in size. The greater number of fruits from affected plants are very small, seldom over two inches in diameter, and the seeds are aborted. The flavor of the fruit is not bad, but such fruits lack the sprightly flavor of normal fruits. Western blight usually appears in June, in plants set in the field in May or earlier.

It is characteristically a disease of early summer and new cases are rarely seen later in the season. In fact it is a common practice where plants show the disease in June to pull them out and replace with new plants in the same holes. Such replants almost never show the disease.

There is a certain relation between the prevalence of western blight and climatic conditions. During normal seasons, i.e., seasons of normal



Fig. 10.—Tomato plant affected with “Blight.”

temperatures, the disease is quite prevalent, reports having been made of losses of over 50 per cent of the plants by this disease. In such normal seasons fairly warm weather in May occurs, followed by a period of decidedly high temperature in June. The statement is usually made that western blight appears after the first “hot spell.” During seasons of subnormal temperatures during May and June, western blight shows a very low percentage of occurrence, even though hot weather follows later in the summer. The disease is also usually most abundant in the hottest, and least common in the coolest portions

of the state. As a consequence of these characteristics, western blight occurs quite regularly every year in the upper San Joaquin Valley, while in the Bay region it develops abundantly only in occasional seasons when high temperatures occur in May and June. Knowledge of the relation of soil temperatures to the occurrence of western blight would be of much interest in this connection. There is also a certain relation between the number of affected plants and the number of plants which have been injured in transplanting. Those plants which develop symptoms of western blight by June 15 have almost invariably shown severe transplanting injury below the ground level. (This is the condition in the Santa Clara Valley). This fact shows an apparent connection with the freedom from western blight of tomato plants grown from seed planted directly in the field and never transplanted.

During the seasons of 1922 and 1923, western blight was not a generally serious factor affecting the acre yield of tomatoes. The loss in plants was from about 5% to as high as 75%, but the average was not above 10%. In that part of the San Joaquin Valley from Fresno on to Bakersfield, western blight was very prevalent and accounted for a loss up to 75% of some fields. The other tomato-growing sections were comparatively free from western blight as compared to past years, at least this is the report had from the growers and field men for the canneries.

There has been no marked difference in susceptibility among the important varieties of canning tomatoes that have been under observation. Several authorities, however, have reported that Dwarf Champion showed marked resistance. (See Humphrey, Henderson, l. c.) Some indication of resistance in this variety has also been seen in California. Western blight shows no relation to the previous planting of tomatoes on the same land, but occurs either on new or old land with no apparent relation to this factor.

Fusarium Wilt.—There is a tomato disease in California which has all the characteristics of the *Fusarium* wilt which is so commonly found in the southern, or warmer states. The characteristics of this disease are at first a rolling of the leaflets which gradually wither and finally die, beginning with the lower leaves. Such leaflets sometimes turn yellow, but this is not an important symptom, since in many cases little change in color is noticed except that in dying the leaves become dry and brown. The plant may wither either as a whole or in one or two stems, but withering does not seem to be as characteristic a symptom in California as might be expected, judging by the behavior of the disease as known in other states. Parts of the plant may at first wilt only during the warmer portion of the day, but in a more advanced

stage the whole plant may become involved, or show decided wilting. Where wilting occurs it is usually confined at first to only one or two stems of the plant, and generally this does not occur until the disease is well advanced within the root system. As the leaves wither and die, the stem finally becomes deprived of all its foliage and begins to die and shrivel, taking on a brown color. The root system is affected and the trouble is evident at first among the smaller roots which become of a darkened color and decayed. The larger roots upon being cut in cross-sections or split lengthwise at first show the fibro vascular tissues to be discolored and turn to a brownish color. Later the whole inside of the root becomes of a dark brown or almost black color. The stem and branches of the wilt-affected plant have a brownish colored vascular system. This color varies from a light brownish color to a deep brown, depending upon the stage of the disease. The discoloration of the fibro-vascular system of the stem is caused by the invading fungus. This discoloration is most marked at the axis and in advanced stages of the disease, the removal of a leaf or branch will disclose an area much more darkly colored than that found in the fibro-vascular system. The pith is not discolored, but remains apparently normal until the plant dies. While no laboratory work has been done by the writer to determine whether this tomato wilt in California is caused by the same organism (*Fusarium lycopersici*) as in the typical disease in other states, the symptoms are identical with those with which he has been familiar in other sections where this fungus is known to be the causal organism. This diagnosis has also been corroborated by Mr. Shapovalov.

Many plants affected by this *Fusarium* wilt are not entirely killed by it, in fact numerous cases have been seen in which 60 per cent or even 80 per cent of the plants were affected, but actually not over 2 per cent died with the disease. In fact it seems to be a more or less general rule that under average conditions in California this disease does not show the virulence experienced in other states. While the disease has been under observation by the writer during only two seasons, there has been no indication of a tendency for it to become more virulent from one season to another. This condition seems to be largely attributable to climatic differences of different seasons. While the number of plants actually killed by the disease does not necessarily show a steady or marked increase when the same land is planted in tomatoes during consecutive years, it is nevertheless true that the fungus shows a decided increase from year to year in its aggregate effects. The large percentage of *Fusarium*-infected plants, whether they actually die or not, is a very positive factor in lowering

the acre yield of tomatoes and this decrease in yield increases rapidly from year to year. One field of about twenty acres illustrates a typical case of this and of the comparative behavior of western blight and *Fusarium* wilt. The development of western blight occurred soon after this field was planted and by June 15th was at its height. After this date very few plants developed the trouble and the affected plants were well distributed in the field to the extent of about 10 per cent of the total number. At this time about 1 per cent of the plants were badly affected with *Fusarium* wilt. The *Fusarium* developed quite steadily during the season until 60 per cent of the plants were affected to a greater or less degree, although not more than 2 per cent of them died on account of the disease. The variety was the commonly planted strain of "San Jose Canner" which shows typically what may be called a partial resistance to the disease. Approximately half of this field had produced tomatoes before this season, the other being new land for this crop. There was as much western blight on the one half as on the other, but the *Fusarium* wilt was a much more serious factor on the older half of the field. In the new portion the wilt was only half as much as that on the other part which had been in tomatoes before.

During the latter part of the canning season a considerable percentage of the fruit from some fields showed a yellow mottling. Upon examination the yellow color was found to be in the outer walls extending through the entire thickness. Field investigation showed that all such mottled fruit came from *Fusarium*-infected plants, but all such infected plants did not produce mottled fruit. In all the tomato-growing sections investigated during the past two seasons, *Fusarium* wilt has been found.

In the Merced district during 1923 whole blocks of Earliana and Stone were ruined by *Fusarium* during June. Actual count showed that not less than 90 per cent of the plants were visibly affected with a proportionate loss of crop. In the vicinity of San Jose, the case of a typical field may be mentioned for illustration: In this field both Earliana and San Jose Canner were grown. The Earliana showed a loss of 20 per cent of the plants on account of *Fusarium* wilt in late July. At the same time the Canner showed very little infection.

In the interior valleys and southern California *Fusarium* wilt is undoubtedly a very serious tomato disease. The same is true in the Bay region and other cooler sections of the state, although the losses there are proportionately less. In the warmer sections there is an actual loss of a considerable percentage of plants, while in the colder

sections of the state the greatest loss from *Fusarium* infection is caused by the lowered producing ability of the plants, rather than by the number actually killed. While the percentage visibly affected by *Fusarium* may be low, an examination of the plants by cutting open the stem and observing the discoloration of the fibro-vascular system may show that 80 per cent of the plants or more are infected by the time that harvest season commences.

Fusarium wilt can be controlled to some extent by crop rotation, but by far the greatest possibility lies along the line of growing resistant varieties. Since the cause of the disease is a soil organism which enters the plant through the root system, such methods as spraying with a fungicide or dusting with sulphur cannot be of any effect.

The most susceptible variety grown in California commercially is the Stone. Numerous cases have been seen of almost total loss of this variety by *Fusarium* wilt. Fortunately a number of varieties have been developed which are highly resistant to this disease. It is recommended that the Stone be replaced by the Norton or Norduke, both of which are of Stone type and red in color. These two varieties have shown by actual test that they are as resistant in California as elsewhere. The Globe is an older pink variety which has considerable resistance and which is suggested to displace Stone for shipping. For canning purposes in those sections not suited for the growing of the Canner, the Norton should be tried. In the Bay region the Canner has shown a considerable degree of resistance to *Fusarium* wilt, partly perhaps on account of low temperatures rather than from actual resistance to the fungus. Comparative tests in that region have shown, however, that it is less susceptible than the Stone.

Fusarium wilt is apparently one of the most serious diseases affecting tomatoes in California, but fortunately one which we have every assurance can be controlled by the use of resistant varieties. In the upper San Joaquin Valley from Fresno to Bakersfield western blight is an even more serious factor, but in the commercial tomato-growing districts *Fusarium* wilt has been found in every field examined and as high as 80 per cent of the plants show infections with this disease at the end of the season. What the cost in tonnage amounts to cannot even be estimated, but it must be a very large one. If we assume that the falling off in wilt which always occurs when tomatoes are grown consecutively for several years on the same land (see page 6) is caused by *Fusarium* wilt, the importance of this disease needs no further exposition.

Nematodes.—In a number of tomato growing sections the Nematode Worm is very prevalent, causing the root knot disease. This is par-

ticularly true in light soils in the San Joaquin Valley and in southern California. Where this pest is present in the soil, the successful production of tomatoes cannot be expected.

Blossom End Rot.—This disease is sometimes serious in tomatoes; one field near San Jose which was condemned on account of it was seen, and no fruit was gathered from the field for commercial purposes. Much study has been given to this trouble all over the country. The general conclusion regarding it is that it is not due to any parasite or pest, but is the result of irregular and scanty irrigation. Fields which regularly receive sufficient water and thorough cultivation do not show this condition.



Fig. 11.—Tomato root affected by nematodes. No remedy except to plant in new land.



Fig. 12.—“Tip Blight” disease of tomato.

Tip Blight.—There has been prevalent in parts of central California during 1923 a disease which for want of a better name will be called "Tip Blight." This disease has been observed in the Bay region and near Suisun. It was first brought to attention by a grower near San Jose, in one part of whose field there was an apparent infection of 75 per cent of the plants. This badly infected area covered about a half acre. The balance of the thirty-acre field showed only an average of 10 per cent the first week of July and did not materially change during the remainder of the season, except that some of the infected plants gradually died down. During August, near Suisun, a number of adjacent fields comprising about 200 acres, showed an apparent infection of 5% to 20%. At Hayward the percentage was about the same as at Suisun, although the infection in spots ran considerably higher. At Milpitas the disease was quite prevalent in the corner of one field, the percentage of infected plants being 40%. Practically every field in the Bay region that has been under observation showed some plants with this disease. But it was only in a few limited spots that commercial losses were caused by it.

The first indication of the disease is a wilting of the soft tips of the stems, the wilting occurring without change of color in either the stem or the foliage. The wilting is followed by the appearance of longitudinal, dark-colored blotches on the stem, the blotches being irregular in size and outline. The fibro-vascular system seems to be clear, but the pith shows rusty to brownish discoloration. In parts of the browned pith there are vacant areas, appearing as if the pith had been destroyed. The impression is often given that an insect had been tunneling through the pith, but no insect has been found at work, nor are there any castings present. There seems to be no opening through which an insect has entered or left the infected stems. During the earlier stages of the disease the pith discoloration extends down the stem about the same distance as do the blotches in the cortex, later the pith discoloration descends without any relation to the location of the external blotches. The cortex blotches occur on the petioles of the leaflets and on the main axis of the leaf as well as on the cortex of the stem. A rather distinctly characteristic spot has been observed on the leaflets of infected stems.

During this year the greater number of infected plants had set a considerable number of fruits before the disease attacked them, or at least before it became apparent, and in most instances this fruit was matured. In other instances the plant died to the ground before the maturity of the fruit. The disease spread slowly during the remainder of the season from July 10 to November 1, but its effect was not so

pronounced nor was it so destructive of the plant as it was in early July. This later infection was confined almost entirely to the tips of the plants and to the petioles and axes of the topmost leaves.

This disease occurred among the plants in a small garden during late August and September, only one plant of twenty being at first affected, but the trouble gradually spread to six of them. Half of the affected plants were cut off some distance below the apparent infection and there was no further development of the disease in the cut-off plants, each of which matured fruit after being topped. During some stages of this disease it could be easily mistaken for *Fusarium* wilt because of the appearance of the dying plant. As the stem dies, the leaflets become dry and brittle and fall off. The stem as it dries turns to a dark brown color and becomes shrunken. During the latter part of the season, from September on to the end of the season, wilting has not been so evident and in most cases developed during this period the tips and leaves have died without wilting.

Gardner and Kendrick⁹ describe, as a form of tomato mosaic, symptoms which appear identical with those of this disease.

Southern Wilt.—During June of this year there appeared among the plants of one field at Merced a peculiar wilting of the axes of the leaves. Upon cutting open the axis, the pith was found to have broken down and in place of it, there was a discolored milky juice. This condition is suggestive of the Southern or Bacterial wilt.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

On the basis of the observations and conclusions contained in this report, the writer would offer the following recommendations as the most promising and practical possibilities of improving the canning-tomato industry in the San Francisco bay region.

1. Any successful effort toward permanent improvement of the canning-tomato-growing industry must come from the canners more than from the growers.

2. It is suggested that the seed beds be planted about February 15th or March 1st rather than January 1st, as at present. This will result in planting in the field younger plants which will better stand the shock of transplanting and be more resistant to disease.

3. No radical changes in present field practice are considered necessary.

⁹ Gardner, M. W., and Kendrick, J. B. Tomato Mosaic. Ind. Agr. Exp. Sta. Bull. 261, pp. 1-24. 1922.

4. The disease commonly called "Blight" in California really consists of two diseases, "Western Blight" and "Fusarium Wilt." The former is peculiar to California and the Northwest. The latter is the common tomato wilt disease of the southern and eastern states.

5. In the most important tomato-growing parts of California, Western Blight is probably less important and Fusarium Wilt much more important than has heretofore been supposed.

6. The cause and specific method of control of Western Blight are still to be discovered.

7. Fusarium Wilt is controllable to a great extent by the use of resistant varieties, supplemented by crop rotation.

8. The present, so-called "San Jose Canner" ("Jap Canner") variety of the San Francisco Bay region constitutes the most promising canning variety for that district, having highly desirable qualities of productiveness, color, flavor, percentage of solids and other canning qualities, and considerable disease resistance. Its principal defects are oversize, rough and irregular shape, too much core, and too long a season required for maturing the crop.

9. The greatest practical opportunity for fairly immediate improvement in quality and production of canning tomatoes lies in improving this variety by selection in the qualities mentioned and in disease resistance.

10. There is no urgent demand for such improvement on the part of tomato growers. The effort to obtain, and especially to introduce such an improved variety must be largely fostered by the canners.

11. The Stone variety is highly susceptible to Fusarium wilt and should be supplanted by Norton or Norduke for canning and by the same (red) varieties and the Globe (pink) for shipping.

12. The development of other new tomato varieties is desirable, likewise knowledge of the nature and control of Western Blight.

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